THE NESTING AND MARKING OF SHIP PARTS CUT FROM STEEL PLATE

by

HARRY HOOPER
CONSULTANT TO AVONDALE SHIPYARDS, INC.
2.20.85

Project No. A813

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **20 FEB 1985**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **The Nesting and Marking of Ship Parts Cut From Steel Plate**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Bldg Bethesda, MD 20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**203**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

PROGRAM MANAGEMENT

This report is one of the many projects managed and cost shared by Avondale Shipyards, Incorporated, under the auspices of the National Shipbuilding Research Program. The program is a cooperative-effort between the Maritime Administrations office of Advanced Ship Development and the U.S. shipbuilding industry.

Executive administration and supervision were provided by Mr. E.L. James, Vice President, Production Planning, Avondale Shipyards, Incorporated; with Mr. Richard A. Price, MarAd Research & Development program manager, Avondale Shipyards, Incorporated.

Project definition was provided by the members of the Society of Naval Architects and Marine Engineers Panel SP-1 Shipward Facilities and Environmental Effects and Mr. R.W. Schaffran, Maritime Administration, Office of Advanced Ship Development.

The special advisory group was made up of the following:

Eugene Blanchard - Vice President, Production
Bob Pourciau - Superintendent, Moldloft
James Wilkens - Group Vice President, Engineering
Alan Nierenberg - Vice President & Chief Engineer
Eugene Aspuru - Manager, Plant Engr'g. & Maintenance
Don Desalvo - Assistant Plant Engineer
Joe Taylor - Superintendent, Pre-Fabricating.

TECHNICAL SUMMARY

In this report, the methods presently used by United States shipbuilders for preparing, nesting and marking plate parts are discussed. The use of existing computer technology is explored as a means for improving these operations by conserving plate and reducing operating costs.

TABLE OF CONTENTS

	Page
Technical Summary	2
Acknowledgements	4
Preface	5
Introduction	6
Discussion	9
Classification of Parts Cut From Steel Plate	9
Cutting With the Oxy-Flame Process	10
Cutting With the Plasma Process	15
Nesting Class 3 Parts Using Numerical Control	15
The Use of Standard Sized Plates vs. Special Sized Plates	19
The Handling of Cut Parts and Scrap	22
Nesting by Computer and Computer Assist	23
The Marking and Coding of Parts	30
Plate Marking by Air Activated Center Punch	30
Plate Marking by Zinc Oxide Powder	31
Plate Coding by Paint Stick	33
Marking and Coding by Matrex Ink Jet Printers	33
Coding by Sticker Label Application	34
Conclusions	37
Shipyards Visited During This Study	39
Shipbuilding Oriented Software Companies Visited During This Study	39
Companies Visited That Offer Nesting Systems	39
References	40
Appendices	
1. The Advantages and Disadvantages Realized With the Oxy-Flame Cutting Process	41
2. The Advantages and Disadvantages Realized With the Plasma Cutting Process	43
3. Some Advantages and Disadvantages Realized When Using Special Sized Plate-in Ship Hull Construction	46
4. Basic Features Required in a Part Nesting System for the Shipbuilder	47

ACKNOWLEDGEMENTS

During this study, a number of shipyards and suppliers were visited. These are listed at the back of the report. The study also required spending many hours with others more knowledgeable in certain areas than the author. During the preparation of the work, I have been fortunate to receive willing and able assistance from all of those contacted for which I express sincere thanks.

PREFACE

Over the past 25 years, the shipbuilding industry has gone from full scale faired hull design with manual part definition and preparation to the use of computerized designs and computer assisted part preparation. During this period of growth, the equipment and the computer systems adopted have varied from yard to yard to suit the needs at the time of purchase. In addition, existing facilities and the historical mode of operation has varied from yard to yard. Therefore, the methods for selecting plate sizes, for nesting parts on the plate and the requirements for marking and labeling cut parts vary from yard to yard.

In preparing this report, the above has been recognized. The various factors that play a role in the final and successfully marked parts are discussed under the appropriate headings.

It is hoped that the information contained herein will not only be found interesting and informative, but that it will also be helpful in lowering costs and improving production.

INTRODUCTION

The nesting of parts cut from rolled plate has for many years been a subject of interest to the shipbuilder. Initially, during the period of full scale lofting and the manual development of shapes from the full scale loft, nesting was done manually, often on the production floor by laying out the parts on the plate. During this period, many of the laid out parts were cut by shears or by small single torch hand guided machines. The next step in the evolution of flame cutting led to the introduction of the 1/10 scale loft and the production of 1/10 scale templates. With these templates it became possible to produce nested 1/10 scale templates where the individual parts were grouped on a scaled shape of the plate to be used. Photographic negatives of the nests were then prepared at a further reduced scale. These negatives were projected on plates fed through a dark projection tower. Operators marked the projected outline of the shapes on the plate. Using the manually marked path, the parts were cut by a manually guided, power or hand operated torch. This required large burning areas and multi-man single torch burning operations, the number depending on the ship production needs. Because of the accumulation of tolerance errors encountered, many parts were cut oversize and trimmed to fit at assembly.

With the advent of the shape cutting machine, it became possible to produce cut plate parts and, in particular, the smaller parts using a full scale paper template and one or more cutting torches, depending on the quantities of parts required.

Introduction of the electronic tracer in the 1940's made it possible to eliminate the hand guided cutting method and quite accurately cut parts from full scale templates with an automatically guided template scanning device.

In the 1950's, it became possible to operate large coordinate driven flame cutting machines from 1/10 or smaller scaled templates. This was accomplished through the use of pilot machines equipped with photoelectric tracing heads that followed the l/10th scaled templates or scaled projections of the original photo negatives. Here again, through the manual arrangement of parts on the scaled plate shape, it was possible to create a nest that improved plate utilization.

In the mid 1950's, the numerical control of machine tools became practical, first with positioning devices and then with contour following devices. Programs for these devices were originally prepared manually and the necessary punched tape was prepared by a manual hole punching device and later by special typewriter machines.

As the numerical controls and machine hardware improved, manual programming became impractical and industry identified a growing need for the development of computer programming and the associated hardware. Because of the initial cost of N/C controls and the associated hardware and the lack of software, the application of N/C to shipbuilding took hold slowly. Initially, some users of the equipment, because of the lack of. computer software for defining shapes, operated from scaled drawings. Tapes were prepared from these drawings through the use of point to point digitizers. Even today, some yards continue to use paper templates and digitizers for some of their programming needs.

Through the years, there has been steady-improvements made in the machine hardware, in the N/C controls and in the associated program software. This has led to the use of powerful high speed servo drives on the cutting machines. This, in turn, has led to a speedup in production through the use of the plasma cutting process and the accurate high speed plate marking at 200 to 300 IPM.

During the past few years, developments achieved through the use of mini-computers and main frame computers have further enhanced the performance of-machines and associated equipment to the point where some advanced systems operate from DNC (Direct Numerical Control) and the use of punched tape has been completely eliminated.

These developments have created an environment requiring improved nesting and marking technology. This report has been prepared to help identify the problems and to help pave the way to both time and material savings through the use of efficient, computer-oriented methods for nesting, marking and coding of flame cut parts.

DISCUSSION

CLASSIFICATION OF PARTS CUT FROM STEEL PLATE:

The steel lift for ordering plate is usually prepared by the engineering department. When preparing this list, preliminary nests of the parts required are usually made. These parts fall into three general classifications as follows:

Class 1 - These are the large parts that may be cut in direct image mode or both direct and mirror image modes. On these parts some layout marking is usually required for referencing them to other parts on the ship's hull. In most shipyards today, these parts are cut and prepared by large numerically controlled cutting machines.

Class 2 - The low quantity smaller parts such as intercostals, web frame sections, equipment mounting brackets. etc.

Class 3 - The high quantity small parts.such as brackets, clips, collars and chocks that are used throughout the construction of the hull.

These three categories can be divided into area groupings of the total plate used with the following approximate values:

Class 1	-	72%
Class 2	-	24%
Class 3	-	4%

These three categories of parts will be further discussed in the following sections on the nesting, cutting and marking of cut plate items.

CUTTING WITH THE OXY-FLAME PROCESS.

When using a large N/C flame cutting machine and the oxy-flame process, it would take 130 minutes to cut the parts shown in Fig. 1 giving a yield of 84%. The total process time would break down as follows:

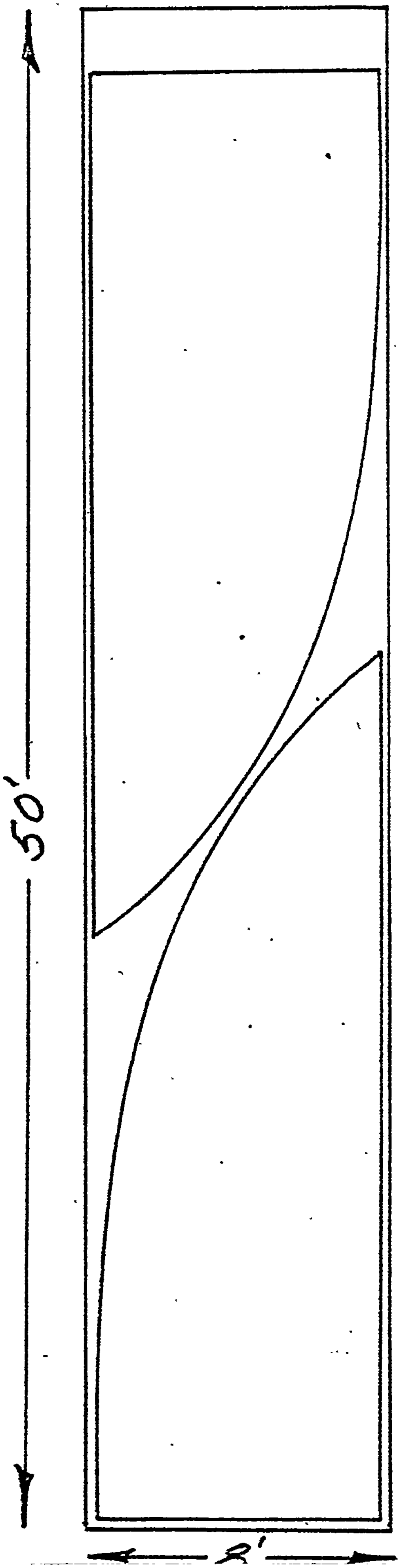
Plate handling time	-	15 mins.
Plate marking	-	10 mins.
Cutting time	-	130 mins.
Part and scrap removal	-	15 mins.
Total time		170 mins.

When adding Class 3 parts to the nest as shown in Fig. 2, the yield increases from 84% to 89%. The cutting time would increase from 130 minutes to 250 minutes and the total process time, including marking and handling, would become 346 minutes or about double the time required in the first case. (See. Fig. 3). Here the scrap saving, valued at approximately $105.00, when weighed against the reduced production of the machine might be questioned. See Fig. 4 for the dollar value of the steel. This helps explain why the production of flame cut parts in many shipyards today is as follows:

Class 1 and most Class 2 parts are produced by the large numerically controlled machines, which not only produce accurate parts, but which also do the plate layout marking automatically. The Class 3 parts are produced in general by any one of the five following methods which include:

1. Flame strip and shear.
2. Flame cut by multi-torch machine with optical template scanner.
3. Flame cut by multi-torch machine with numerical - control.
4. Plasma cut by single touch machine with numeri–cal control.
5. Manual layout and. use of single torch manually guided machines.

With all but 3.and 4 above, these methods require a paper template, a wooden template or a manual layout.



YIELD: 84%

TYPICAL PART
CUTOUTS NOT SHOWN

Fig. 1

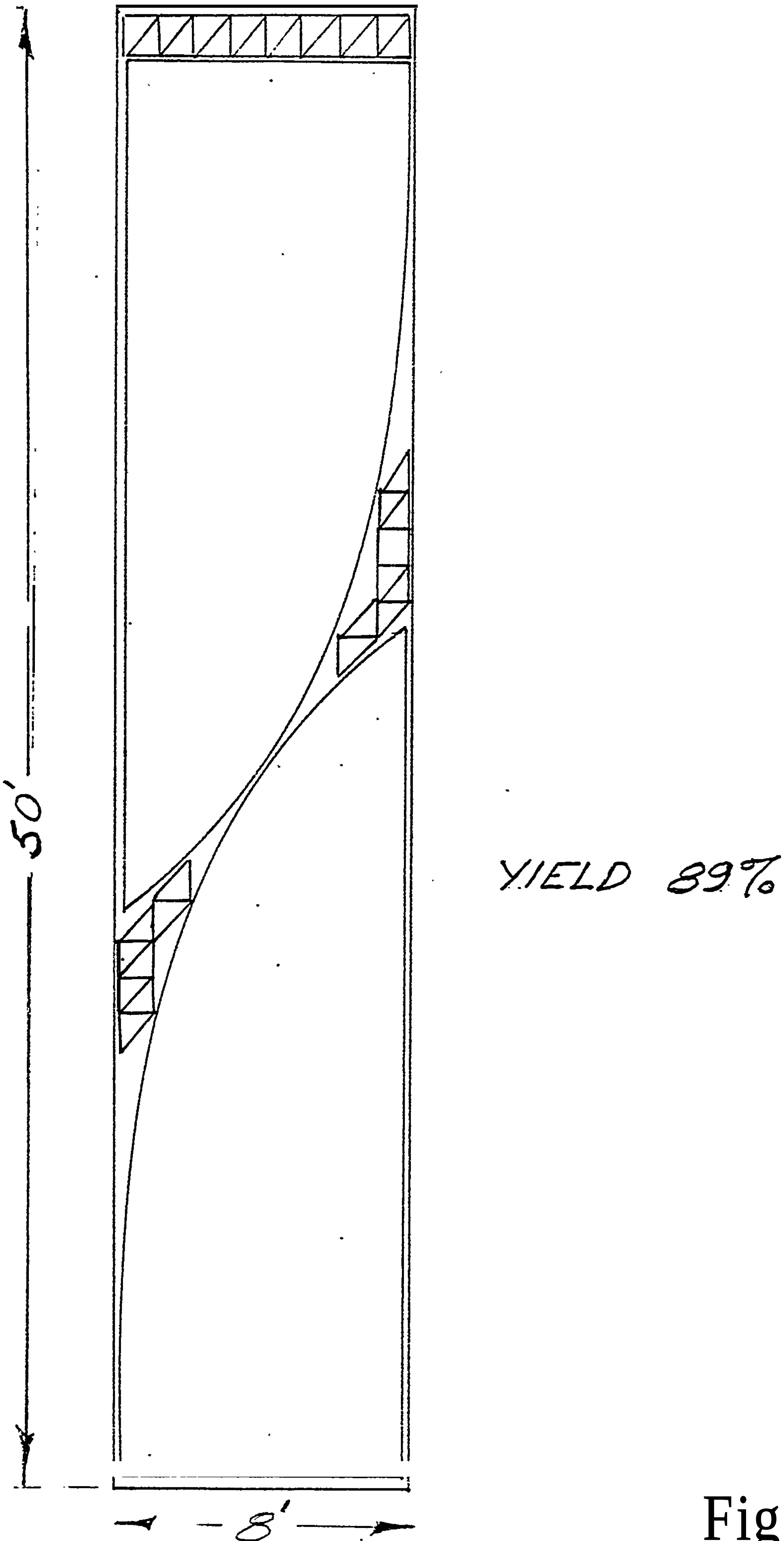


Fig.2

PROCESS TIME FOR PRODUCING PARTS SHOWN ON FIG. 1 AND FIG. 2.

A. Flame Cutting and Paint Stick Coding:

Operation	Fig. 1 time - mins.	Fig. 2 time - reins.
Plate handling	15	15
Plate Marking	10	30
Cutting time	130	250
Part and scrap removal	15	37
Total time	170 mins.	332 mins.

B. Plasma Cutting With Paint Stick Coding:

Plate handling	15	15
Plate marking	10	30
Cutting time	22	40
Part and scrap removal	15	37
Total time	62	122

C. Plasma Cutting With Label Coding:

Plate handling	15	15
Plate marking	10	16
Cutting time	22	40
Part and scrap removal	15	37
Total time	62	108

Fig. 3

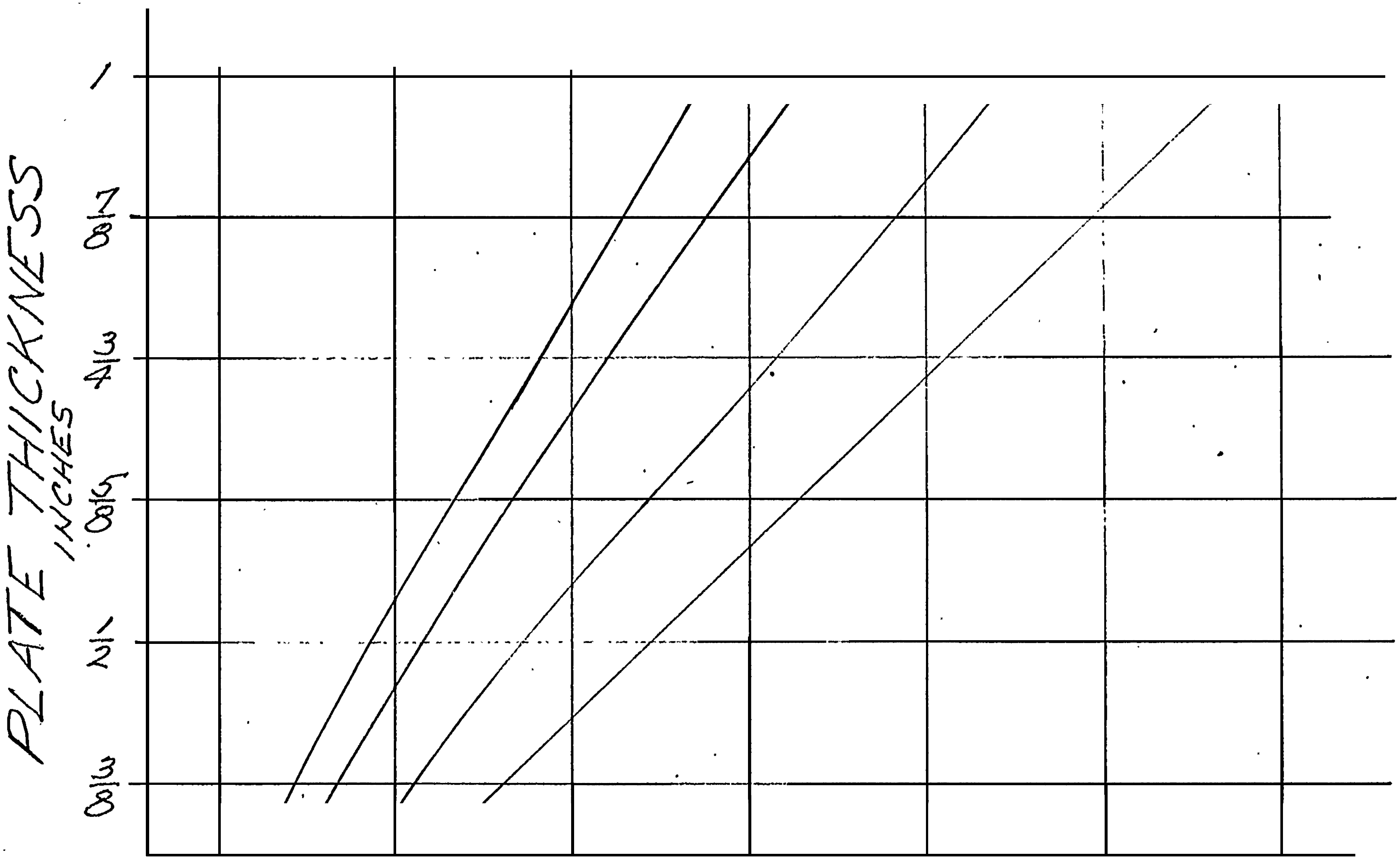


Fig. 4

APPROX. DOLLAR SAVINGS FOR EACH % INCREASE
- PART YIEL. FROM CARBON STEEL PLATE
(MAT'L ONLY)

On Fig. 5, the results of a time study for producing brackets by each of the above methods is listed. Usually. the material used to produce these Class 3 parts is the drop-offs from the large N/C machine or machines. In the study, the material cost indicated is for new plate.

The advantages and the disadvantages experienced with the use of the oxy-flame cutting process are listed in Appendix 1.

CUTTING WITH THE PLASMA PROCESS.

During the past several years, the advances made in the development of both hardware and software have made it possible to very effectively produce steel ship parts with the plasma cutting process. See Fig. 6 for cutting speed comparisons.

When using the plasma process for cutting the nests shown on Fig. 1 and Fig. 2, the time required is reduced considerably as shown on Fig. 3. Through the use of the plasma cutting process and a good part nesting routine, significant savings can be realized in producing a mix of Classes 1, 2 and 3 parts as shown on Fig. 7.

The advantages and disadvantages experienced with the use of the plasma cutting process are listed in Appendix 2.

NESTING CLASS 3 PARTS USING NUMERICAL CONTROL.

At present, in many shipyards, most Class 3 parts are cut through the use of templates. To include these parts in an N/C nesting program would require numerical control program preparation and the elimination of template use. To effectively use these programs, the smaller flame cutting machines, now equipped with optical template scanners must be equipped with CNC controls. The CNC controls used should be capable of

RESULTS OF MATERIAL AND TIME STUDY FOR
PRODUCTION OF 136 - 14" x 14" x 1/2" STEEL BRACKETS.

	.METHOD	YIELD	LABOR COST	MATERIAL COST	TOTAL COST
1.	Flame strip* and shear.	95%	$ 65.50	$ 551.00	$616.50
2.	Flame cut using four torches and optical scanner.	65%	62.50	806.15	868.65
3.	Flame cut using four torches and CNC.	85%	53.75	616.47	670.22
4.	Plasma cut using one torch and CNC.	85%	53.25	616.47	669.72
5.	Manual layout, flame cut using track machine.	90%	543.00	582.22	1,125.22

Coding by paint stick method included in above $ 14.44

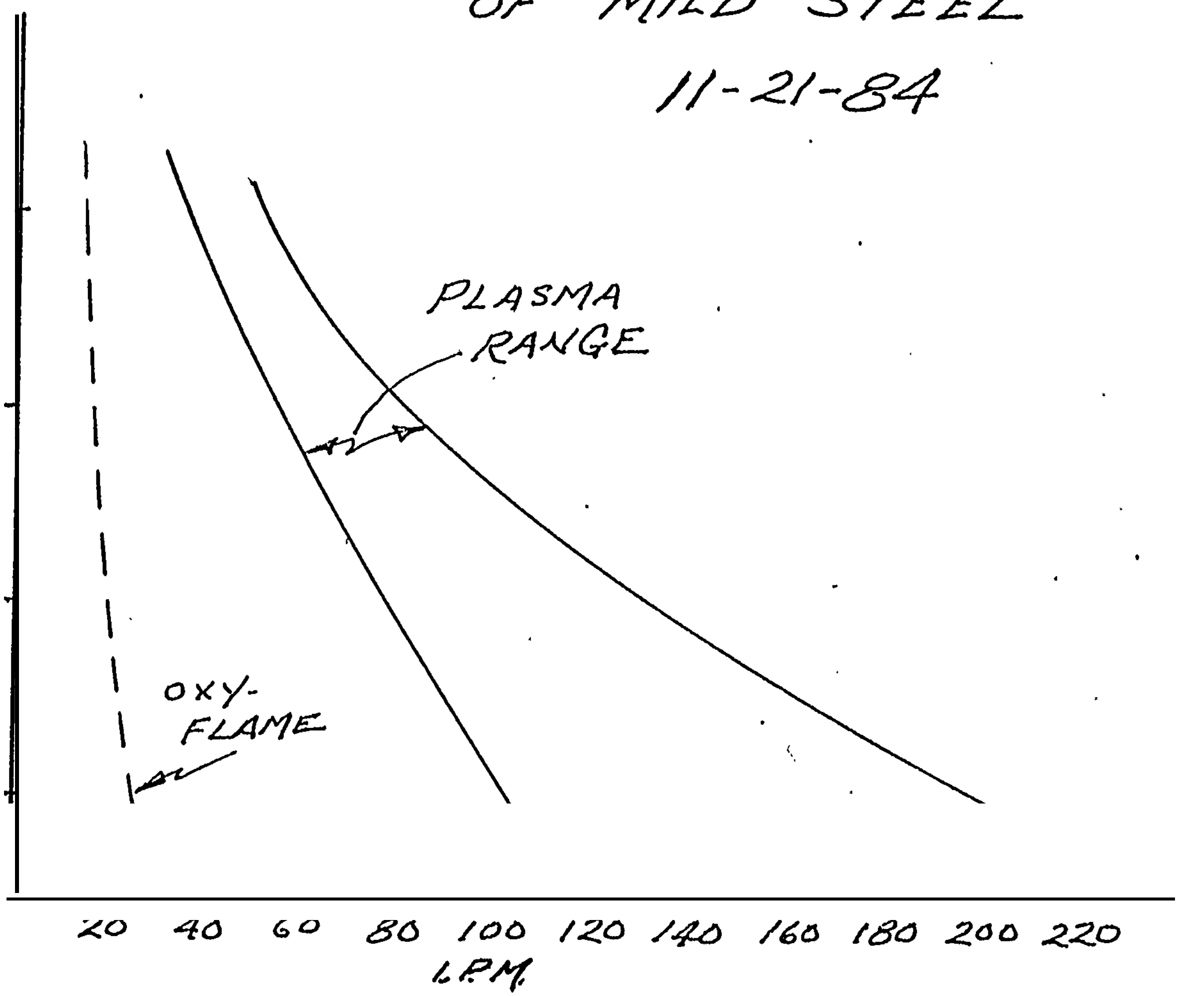
Coding by DNC label - $ 3.78

*Limited to straight line cutting only.

Fig. 5

APPROX OPERATING RANGES
OXY-FLAME & PLASMA CUTTING
OF MILD STEEL

11-21-84



Based on blished Data Thermal Dynamics Hypertherm

Fig.6

AVERAGE LABOR AND MATERIAL COSTS FOR PRODUCING A TON OF FLAME CUT PARTS FROM 1/2″ STEEL PLATE.

	Labor		Material - yield		
	Oxy-flame	Plasma	80%	85%	90%
Class 1 parts 72%	$ 8.43	$ 3.79	$473.40	$445.55	$420.80
Class 2 parts 24%	4.90	1.82	157.80	148.52	140.27
Class 3 parts 4%	7.60	3.47	26.3	24.75	23.38
Totals: 100%	$20.93	$9.08	$657.50	$618.82	$584.45

NOTE : These figures are to be considered for comparison. only, and may vary from yard to yard. They are presented to indicate the relative value of a good nesting system for producing a high yield of parts per ton of steel purchased.

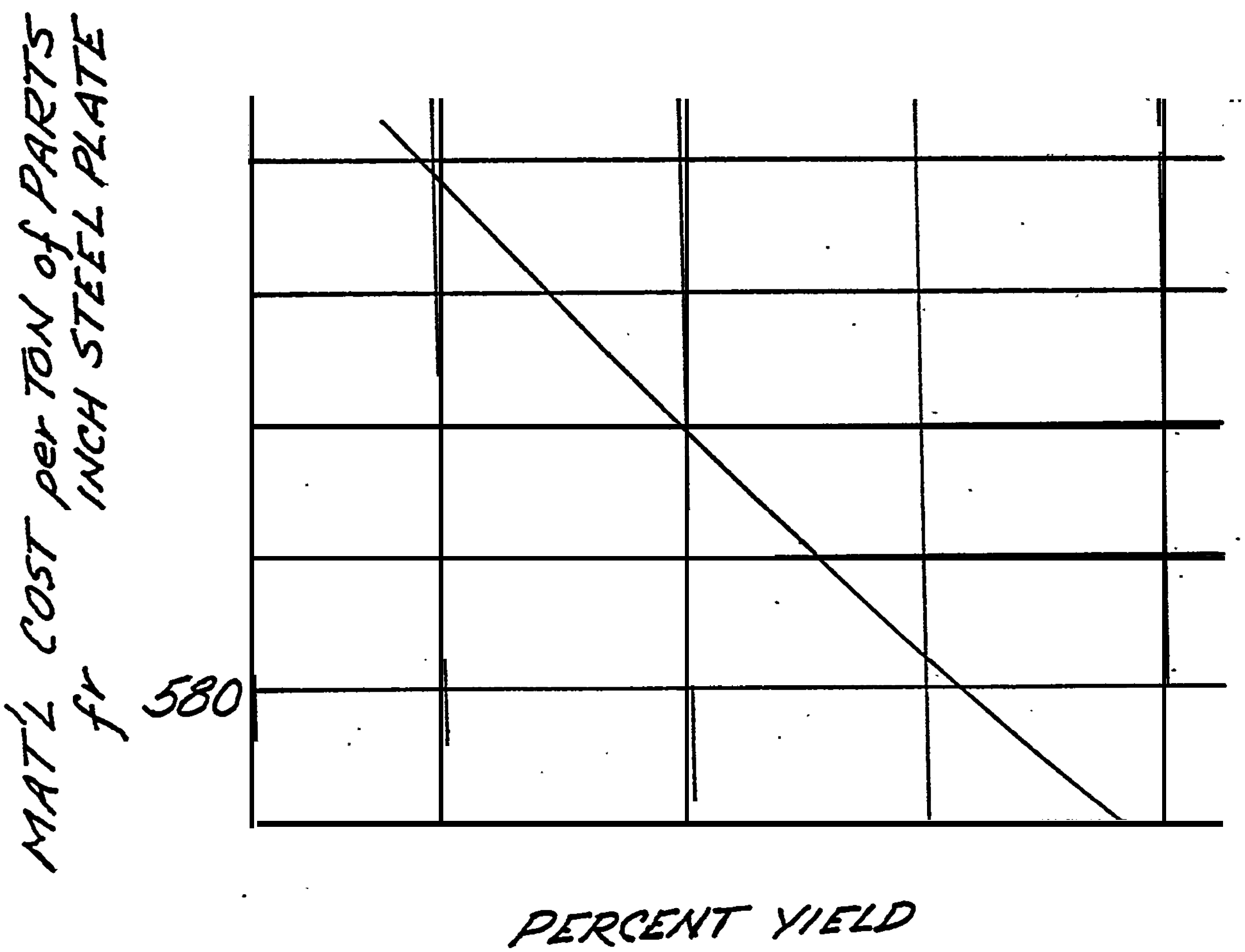


Fig. 7

accepting the same input programs that are used on the large machines. This input should be by punched tape or preferably DNC (Direct Numerical Control) as shown on Fig. 8. By so doing, any of the parts not included in the major machine nests, could be included in the nest assigned to a secondary machine. In addition, the flexibility would allow the major portion of the nest to be executed on the large machine and the remainder carried out on the smaller machine. An example of this is shown on Figs. 8 and 9.

THE USE OF STANDARD SIZE PLATES VS. SPECIAL SIZED PLATES.

Today, construction by unit is accepted practice in the building of ships in the United States. In the interest of controlling inventory and yet providing the parts as they are needed, the parts are cut only as they are required. This procedure sometimes places some restraints on the nesting efficiency possible because of the limited number of some parts needed. Some yards, when preparing the steel lift requirements, follow a PreliminarY nesting procedure from which the plate sizes to order are determined. Others orient their steel lift requirements around a limited number of standard sizes. When doing so, an attempt is made to select those sizes that will result in a minimum of welded joint footage without introducing stress or other problems in the hull assembly. Still others use a mixture of special sizes and standard sizes.

One yard visited made a study of plate yield over a one year period. The results of their study indicated that as the use of standard sizes increased, the yield decreased. This is a difficult subject to work with because an increase in plate yield does not necessarily point to a reduction in production costs . If the system is not properly analyzed and time balanced, efforts made to increase the plate yield could outweigh

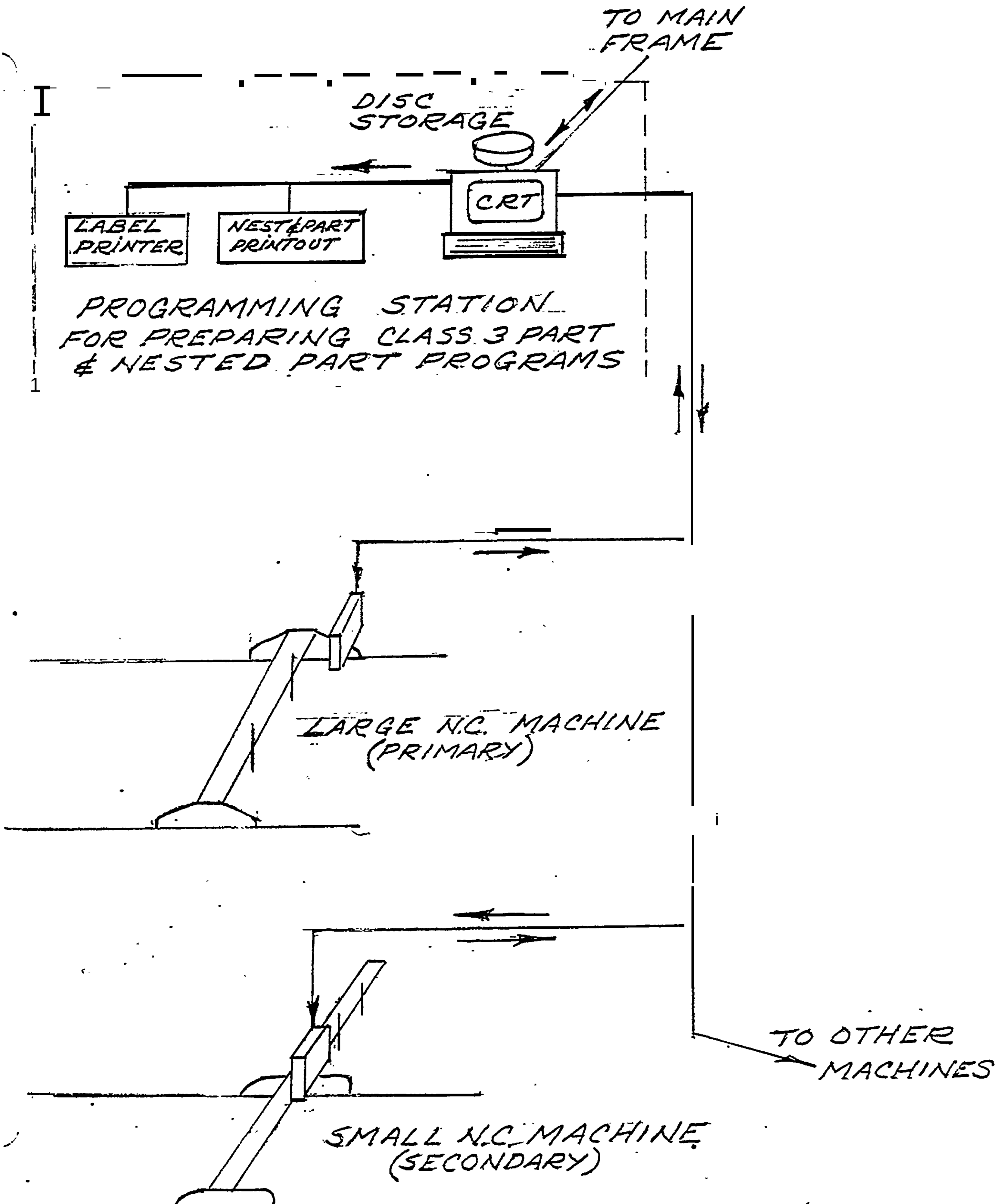

TO MAIN FRAME
DISC STORAGE
CRT
LABEL PRINTER
NEST & PART PRINTOUT
PROGRAMMING STATION FOR PREPARING CLASS 3 PART & NESTED PART PROGRAMS
LARGE N.C. MACHINE (PRIMARY)
TO OTHER MACHINES
SMALL N.C. MACHINE (SECONDARY)

Fig. 8

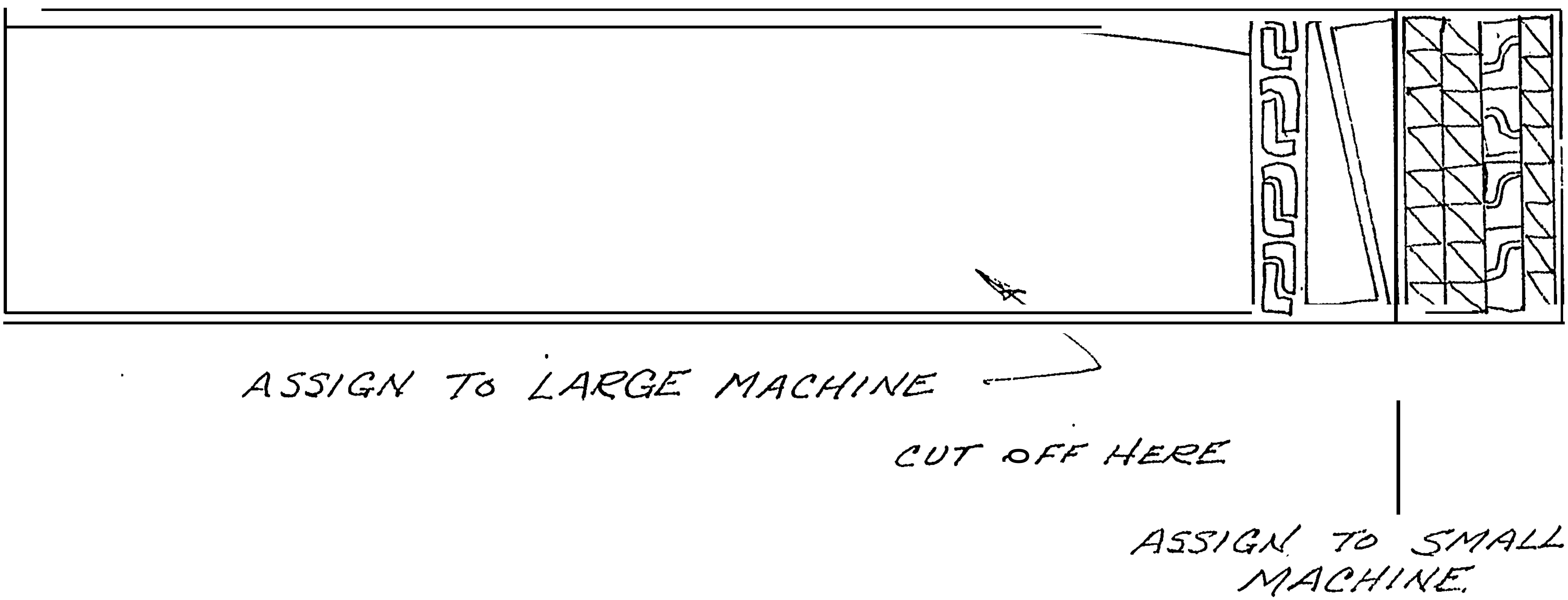

ASSIGN TO LARGE MACHINE
CUT OFF HERE
ASSIGN TO SMALL MACHINE.

Fig. 9

the savings in plate costs by an increase. in labor costs and time delays. The advantages and disadvantages realized with the use of standard and special sized plate are listed in Appendix 3.

THE HANDLING OF CUT PARTS AND SCRAP.

The machine cutting and marking time and the method used for on-loading plate and off-loading parts and scrap plays an important role in the overall cutting operation and the nesting method employed. For cutting the Class 1 and Class 2 (Pg. 9) parts, a double cutting table arrangement that allows for side by side and end to end plate placement is quite popular. This arrangement and the use of multi-magnet lifts allows for operation over one double setup while unloading and reloading on the second double setup. Thus the cutting machine's duty cycle is increased since it can be kept busy cutting during the unloading and loading operations.

When using the oxy-flame cutting process, the nesting of small Class 3 parts with the larger Class 1 and Class 2 parts is often considered impractical because of the time imbalance encountered. See Fig. 3. Usually, in an operation of this type, the plate drop-offs are moved to a staging area for use on smaller machines for fulfilling the Class 3 part requirements. If the remnant is small in area or very irregular in shape, it is often scrapped. Where the remnant is used and the Class 3 parts are cut on a template guided flame cutting machine, the yield is often less than 50%.

To increase the available machine cutting time, some yards use removable plate supporting trays. Here the cut parts and scrap are removed at one time and deposited in a staging area where the scrap and parts are dealt with. The trays are then reloaded for return to the cutting machine's work table. With this method, additional floor space is required for accommodating the trays.

Where access to the machine cutting area does not allow for overhead crane loading a-rid unloading, the use of movable cutting tables is one solution used. At the end of the cutting and marking operations, the table is moved into a staging area for further processing. When the parts and scrap are removed, the table is reloaded and circulated back to the machine for the cutting and marking operations.

Very often, the amount of small parts produced on the automatic N/C machines is very limited so-that the machine can meet the large part assembly requirement of the yard. This often is done at a sacrifice in efficient plate utilization. By implementing the machine arrangement shown on Figs. 8 and 9,this problem can be solved and greater efficiency realized.

NESTING BY COMPUTER AND COMPUTER ASSIST.

Computer oriented nesting systems can, in general, be divided into two types. The first is known as "Interactive Nesting" which is a semi-automatic system. It involves the use of a CRT screen, a cursor and a keyboard. Parts are called up from the computer data base and are moved and rotated by keyboard or cursor input to form a desirable nesting arrangement in the plate area shown on the screen. A bump feature allows for the automatic spacing of the parts to a predetermined amount. Other automatic features usually include:

1. Automatic blowup enlargement for examining intersecting lines and possible overlap.
2. Sequential numbering for part identification.
3. Marker and cutter sequence by cursor or keyboard control.
4. Automatic printout and storage of the completed nested programs.
5. Inventory countdown so that-parts are not unnecessarily duplicated.

The second type of computer nesting is an automatic system where the plate size and the parts to be nested are keyboard identified. By keyboard request, the parts are automatically nested and identified by sequence number. With systems of this type, the final nest is stored under an assigned number and a hard copy printout provided.

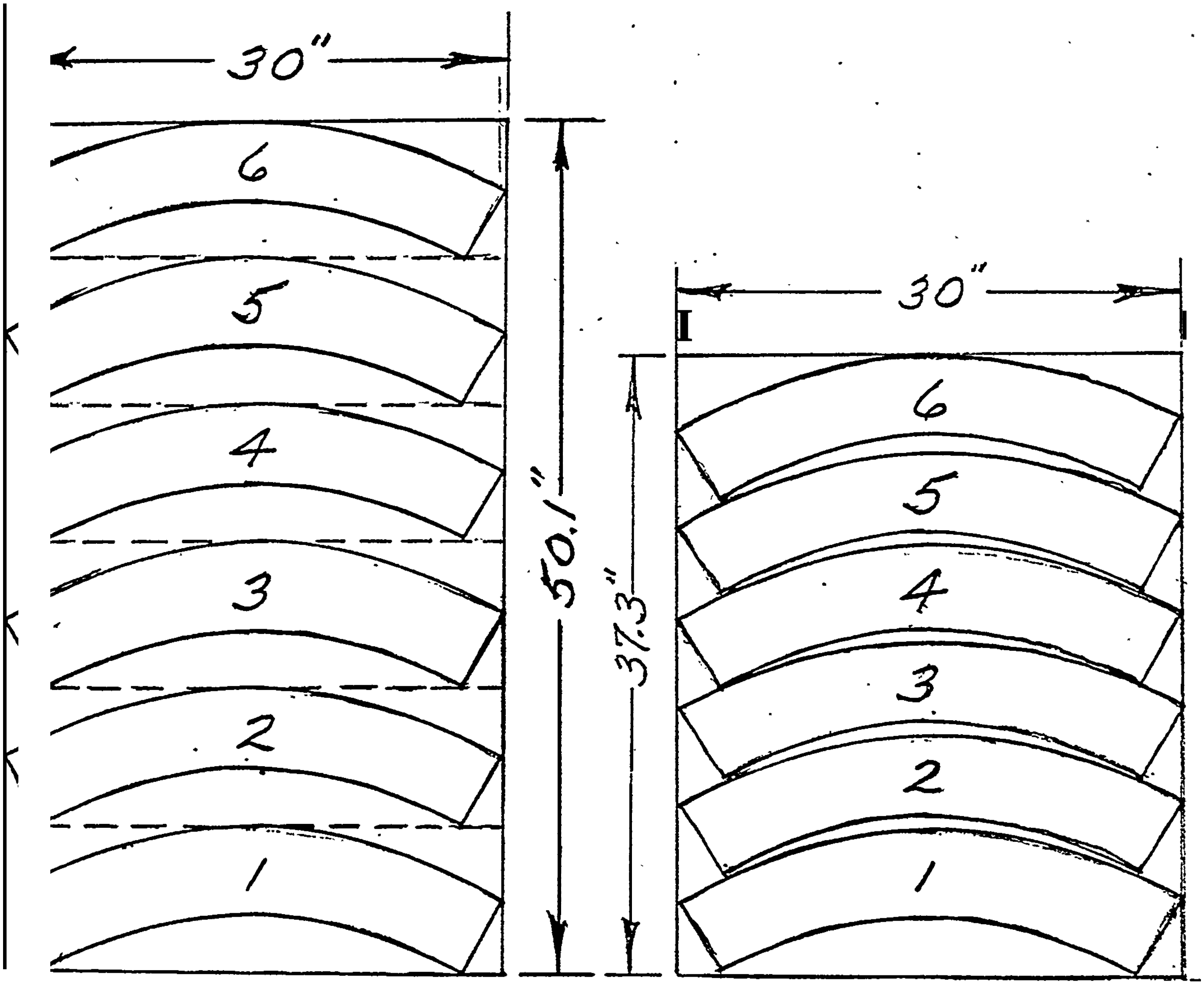
The most popular algorithm used by systems available today involves the surrounding of the part to be nested by a rectangle and rotating it so that its longest side is parallel to the X or Y axis in the program. See Fig. 12. Part nests prepared with the rectangular fitting method can easily be recognized because adjoining parts do not overlap into the arc or other concave areas as shown on Fig.10.

Interactive nesting lends itself well to parts included in categories 1 and 2 mentioned earlier in this report, and where special sized plates are used.

Automatic nesting lends itself well to parts-included in categories 2 and 3. To allow for efficient plate utilization where rectangular nesting is used, the individual part programs being nested should be grouped into two or more parts closely representing a rectangle in shape and stored in this form as shown in Fig. 11.

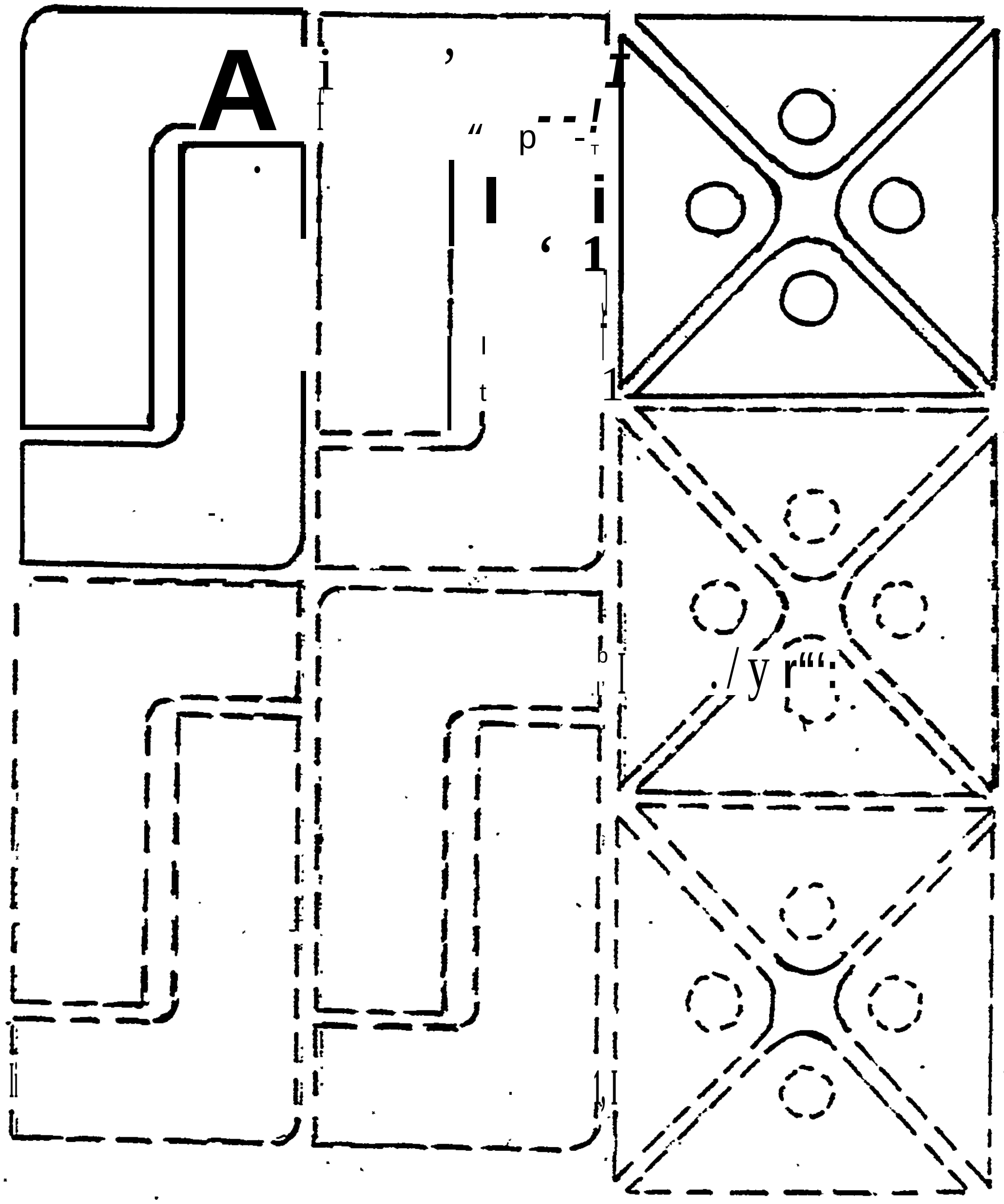
Other more complex nesting algorithms are available that result in a denser part arrangement. Fig. 13 illustrates the results of part nesting using such a system. Implementing nesting systems of this type usually requires that the part program be generated on-a satellite computer or main frame computer and down loaded to a satellite programming station for the part nesting and machine program assignment. In addition to the nesting capabilities, program stations available today allow for part program and CAD-CAM (computer-aided design and computer-aided manufacture) development of parts.

Regarding the use of computers, there are different-schools of thought concerning how they should be applied to the complete operating system. One school believes there should



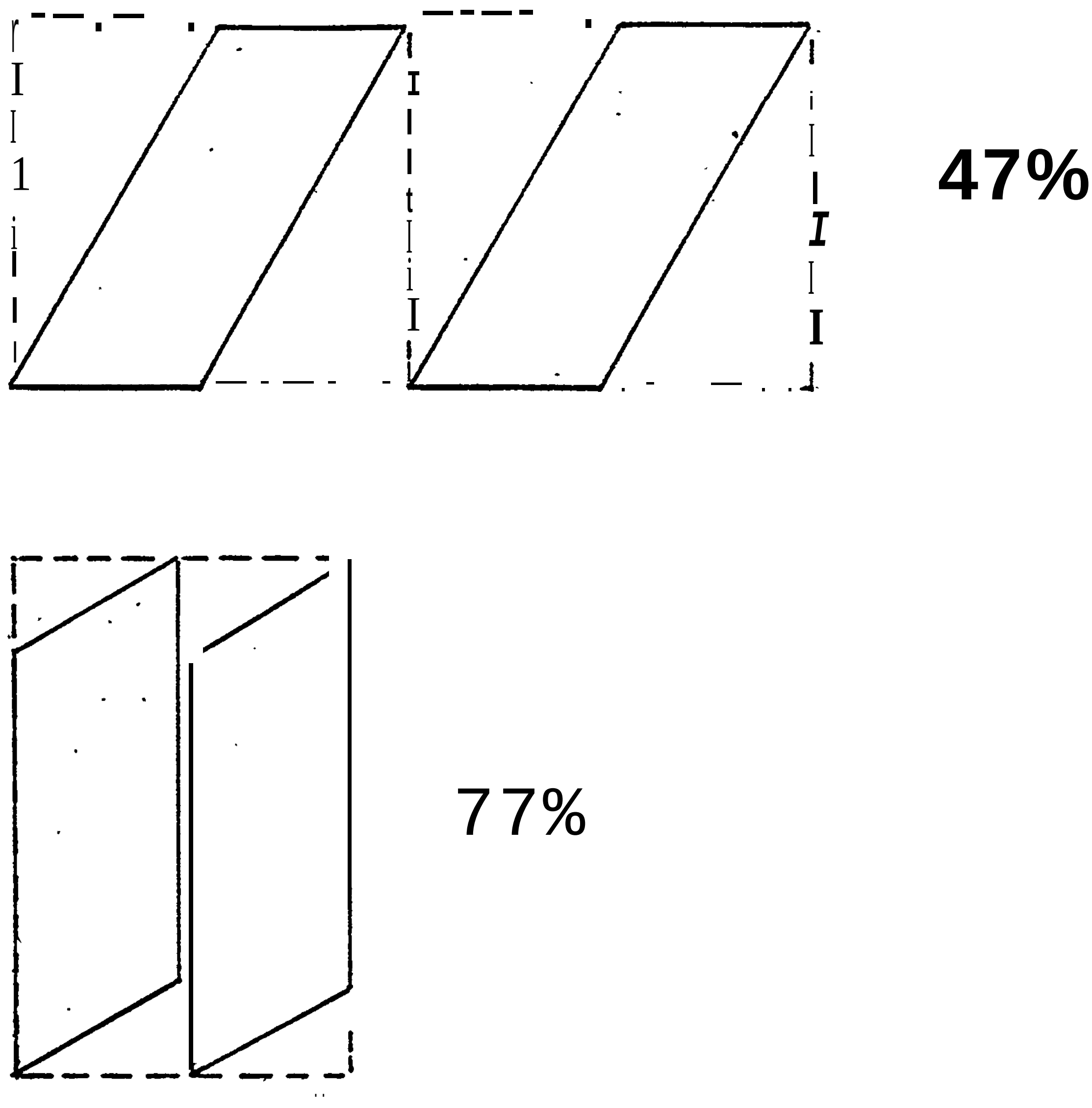
Examples:
Nesting of Ring Segments by Rectangular Fitting and Interactive Graphic Methods.

Fig. 10



GROUPED PARTS FOR NESTING
BY THE
RECTANGULAR FITTING METHOD

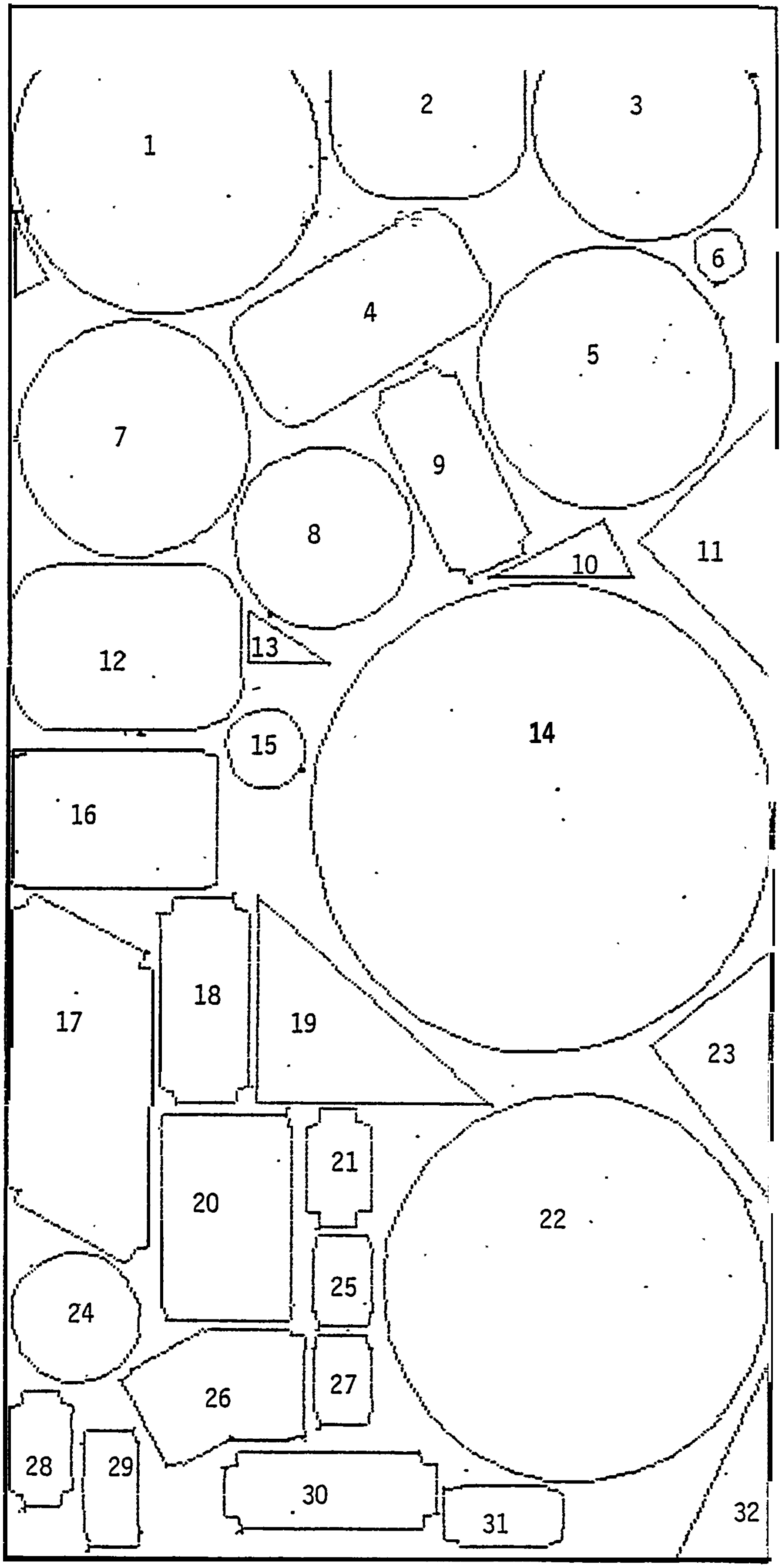
Fig. 11



EXAMPLE: PART ROTATION FEATURE USE IN NESTING BY RECTANGULAR FITTING METHOD TO IMPROVE EFFICIENCY OF YIELD

Fig. 12

NC Part: 642o101.all Thu May 10 11:16:10 EDT 1984 b cybermation, Inc.



.Percent Used : 85. 5

RECTANGULAR ALGORITHM.

be one main frame computer for controlling all systems of operation. By so doing, the following advantages are claimed:

1. There is one main source of basic data information and hence a minimum of error introduction.
2. Changes in design and information update automatically reflect in the computer data output.

The disadvantages realized, however, include the following:

1. Computer downtime may render all systems inoperable.
2. As the computer system grows-in complexity, software problems grow and become increasingly more difficult to cope with. This is particularly true with changes in personnel. There are many ways of constructing the mathematical approach and the solution sequence of the formulas used in software derivation. In addition,. overlaps or ommisions in the software are often not uncovered until after many hours of use. Unless the person attempting to solve a problem is fully aware of the approach taken by the author, a satisfactory solution to the problem becomes very difficult to solve.
3. A computer, regardless of its capacity, sometimes is called on to solve complex, time consuming problems. As more and more demands are made on the main frame. computer, and the job priorities change, its response time can grow slower to the point where it can result in a production slowdown. This could cause a cost increase that could exceed the planned dollar saving in material and process time.

There is a growing trend today to the use of one main frame computer for the basic data base information and an array of smaller computers for setting up and carrying out the detailed assignments as shown in Fig. 8. The advantages of such a system are:

1. Basic data requirements can be called down and stored on a disc in off time and held in readiness for rapid processing as required.
2. Main frame computer downtime does not necessarily affect the operation and hence operating time is minimized.
3. Software problems become local problems that can more readily be handled and solved.

4. New computer production processing methods available fro-m various suppliers can be more readily implemented.
5. The use of one main frame and an array of satellite computers today could be more cost effective since it offers greater overall computer capacity for a lower capital investment in some cases.

A specification entitled, BASIC FEATURES REQUIRED IN A PART NESTING SYSTEM FOR THE SHIPBUILDER, is included in this report. See Appendix 4.

THE MARKING AND CODING OF PARTS.

In the production of plate parts for ship construction, each part produced requires identification marking. Many of the parts also require location marks for referring them to mating parts. In this report, identification marking is referred to as "coding" and dimensional marking is referred to as “plate marking”. These are two distinct-and different operations and in this report will be discussed as such.

plate Marking by.Air Activated Center Punch.

Most large flame cutting machines controlled by CNC in the U.S. today are equipped with plate marking equipment. The most popular type used is the air activated center punch. It consists of an automatic air activated center punch that is located on the flame cutting machine’s torch carriage. It is usually located a fixed distance behind the center of the cutting torch’s nozzle. By locating the marker behind the cutting torch in the direction of the long axis, the resulting marks are correct whether the machine is cutting in the direct image or mirror image mode. When used, the marker is automatically brought into the torch plate position for the marking operation by a fixed offset amount. While the center punch type plate marker offers many desirable features to the

user, it does have some disadvantages such as:

1. Maintenance costs are relatively high because the parts wear and require repair or replacement to maintain accuracy.
2. The operation is noisy.
3. The automatic center punch cannot effectively be used for applying numbers or letters to the plate parts.

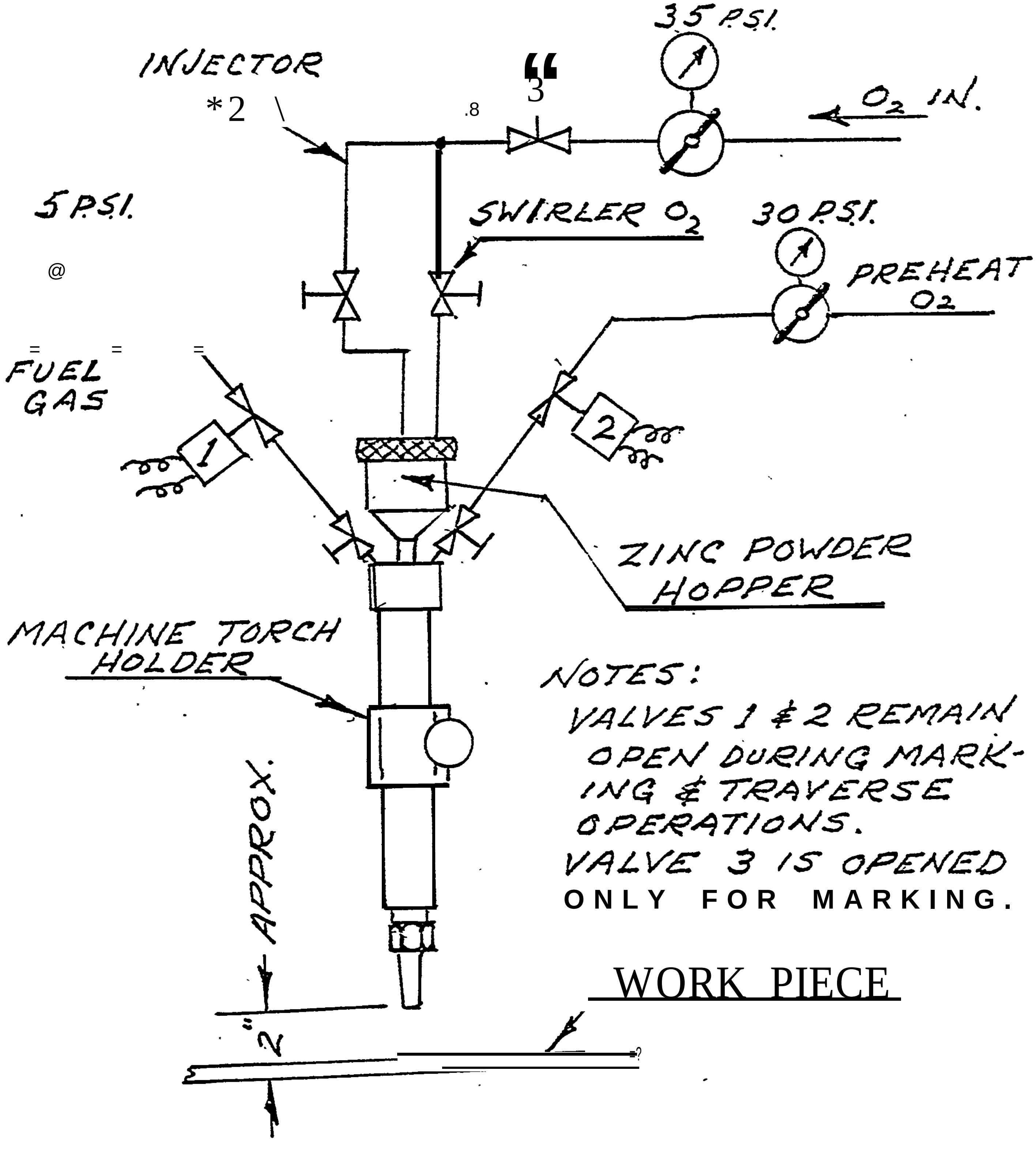
Plate Marking by Zinc Oxide Powder.

Another marking method used involves the application of a fine line of zinc. oxide. This marker unit produces a small amount of fluidized zinc powder that is oxidized in a small stream of oxygen. At the exit point of the discharged fluidized stream, oxy-fuel preheat flames surround the powder stream, conditioning it and causing it to deposit a fine durable white zinc oxide line approximately one millimeter in width on the plate.

There are at least two designs of zinc powder markers in use today. One design uses automatic ignition and requires that the flame be turned on and off each time the marker is used. The other design separates the fluidized zinc oxygen stream from the preheat flames so that the preheat' flames can be left lit during the marking operation. With this arrangement, the fluidized stream is turned on and off automatically as. required during the operation. It has also been determined that a powder marker can operate without automatic height sensing. Experience with the marker indicates that one hopper charge of zinc oxide powder lasts several eight-hour shifts. A diagram of the latter powder marker with pressure settings is shown on Fig. 14.

Some of the advantages offered with this type of marker are:

1. It is a noiseless operation.
2. It can be used for applying sequence numbers to plate parts.
3. Low maintenance is required since it uses very few mechanical parts.



TYPICAL POWDER MARKING TORCH ARRANGEMENT FOR PROGRAMMED PLATE MARKING

Fig. 14

Plate. Coding by Paint Stick.

In all of the yards visited during this program; paint stick coding was the method used for identifying plate parts. In a few isolated cases, hammer die imprint was used on shipboard parts. On Class 1 and Class 2 parts*, the paint stick coding information is manually applied to the plate parts during the machine marking and cutting operations. With the Class 3 parts, the coding is applied either before or after the cutting operation, depending on the method used. While paint stick coding has proven to be a successful method for applying identification marks to plate parts, it does have the following disadvantages:

1. It is a time-consuming method and depending on when applied, it can cause delay in the cutting machine's production of parts. This is one of the reason-s today why more small Class 3 parts are not nested with Class 1 and Class 2 parts in some shipyards.
2. Paint stick marking is always subject to error possibilities on the part of the operator who could, by mistake, apply incorrect information.
3. It is always subject to error by the user because of handwriting misinterpretation.

Marking and Coding by Matrix Ink Jet Printers.

There are several types of Matrix Ink Jet printers-on the market today. These units are programmable non-contact spray type markers with one or several heads for printing single-line or multi-line information in one pass. They are being used mainly in the packaging industry.

Through the use of a rotating head for supporting the marker, it is possible that both plate marking and coding operations could be carried out as part of the N/C program. However, some difficulties may be experienced with the small Class 3 parts where a simplification in the coding procedure is needed the most. Many of these parts would require that the matrix letters be small in size. For example, where a part

*See page 9.

is 3" x 10" in size, the height of the letters could be no larger than 3/8th of an inch. With. the Iargest Class.1 and Class 2. parts, the height: of.the letters. should be 1 to l1/2 inches. To further meet the needs of the yard, the jet printer system should be adaptable to the smaller flame cutting machines in the system. This would require bringing the jet printers to the work pieces. Bringing the work pieces to the jet printer, in most cases, -would not be practical because of the material handling problems it would impose.

While the idea of jet printers may have some appeal, a considerable amount of development work is needed in both hardware and software for it to become economically feasible for coding and marking flame cut parts in the shipbuilding industry.

Codinq by Sticker Label Application.

Today, there are available CAD-CAM sheet metal systems that provide a printout of the nested parts and gummed labels with printed coding information required on each part. Such a system is at present being used at the Avondale Shipyard in New Orleans. The parts in the nested printout and the stickers are automatically numbered in sequence" so that the operator can identify each part in the nest and apply the appropriate sticker to it.

There is software available with most marine programming systerns used today that allows for sequential number printout on nested programs p-reduced by drafting machines". With little change in the machine program, this could be added to the machine's marking operation. A typical part nest printout and the accompanying. sticker printout is shown on Fig. 15.

Such a system, used in conjunction with the powder marker discussed previously would enable the flame cutting machine to write scaled numbers on the individual parts in the program.

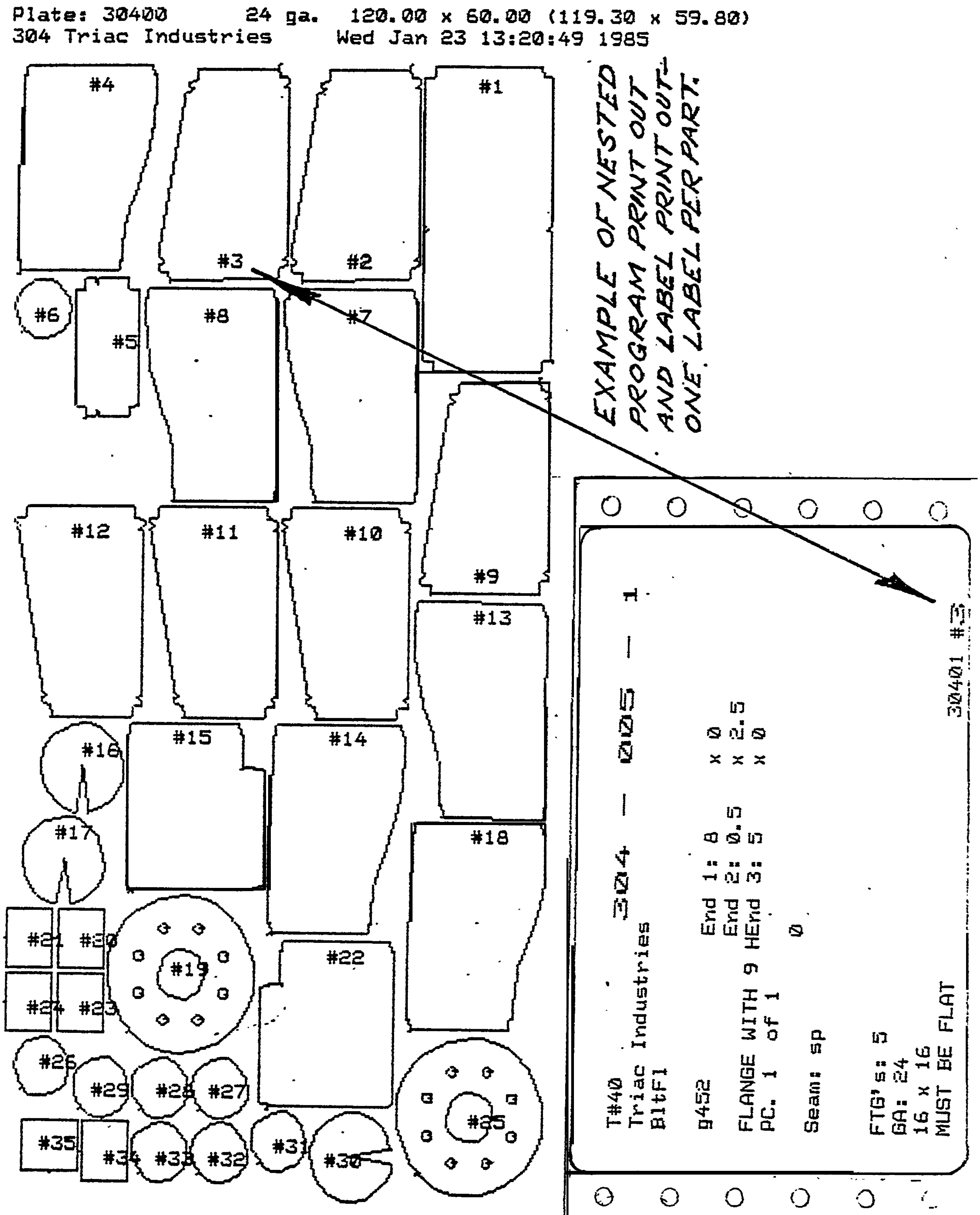


Plate: 30400 24 ga. 120.00 x 60.00 (119.30 x 59.80)
304 Triac Industries Wed Jan 23 13:20:49 1985
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
#12
#13
#14
#15
#16
#17
#18
#19
#20
#21
#22
#23
#24
#25
#26
#27
#28
#29
#30
#31
#32
#33
#34
#35
EXAMPLE OF NESTED
PROGRAM PRINT OUT
AND LABEL PRINT OUT-
ONE LABEL PER PART.
304 — 005 — 1
T#40
Triac Industries
BltF1
g452 End 1: 8 x 0
End 2: 0.5 x 2.5
FLANGE WITH 9 HEnd 3: 5 x 0
PC. 1 of 1 0
Seam: sp
FTG's: 5
GA: 24
16 x 16
MUST BE FLAT
30401 #3

Fig. 15

The operator, rather than writing the code information on the plate, would apply the appropriate label to the part. Label material that weathers well is available. The advantages of such a system are:

1. It will speed up the coding process and help make it possible to include Class 3 parts in the nests of Class 1 and Class 2 parts.
2. It will minimize the error incident possibility since the coding would appear in a format that is controlled by the data processing system.

CONCLUSIONS

Through the use of modern computer oriented techniques in the preparation of ship parts cut from rolled steel plate, the following can be realized:

I. A reduction in plate costs by:

1. Introducing a computer program station with interactive and automatic program capabilities for:

   1a. Transferring Class 1 and Class 2* part programs from the main frame computer to the program station with hard disc storage for prompt use in preparing nested programs.

   1b. The automatic part programming and combining of Class 3 parts for efficient plate utilization. This will also eliminate the need. for preparation of paper templates and many of the wooden templates now used. In addition, this will eliminate template storage problems.

   1c. The preparation of nested programs of Class 1, Class 2 and Class 3 parts. See Fig. 7 for evaluation of the savings possible and Appendix 4 for BASIC FEATURES REQUIRED IN A PART NESTING SYSTEM FOR THE SHIPBUILDER.

2. Equipping secondary shape cutting machines with numerical controls in place of optical template following devices and tying the machines into a DNC network as shown on Fig. 8. By so doing:

   2a. The operations of the secondary machines can be integrated with that of the primary machines and an improvement in efficiency realized. See Figs. 7 and 9.

   2b. The number o-f special sized plates required can be reduced thus leading to a reduction in material and handling costs. See Figs. 2 and 9.

* See section on CLASSIFICATION OF PARTS CUT FROM STEEL PLATE. (page 9.)

II. A reduction in the time and labor costs by:

1. Using the plasma cutting process in place of the oxy-flame cutting process for contour cutting of rolled plate less than one inch in thickness. This will result in an increase in cutting speed and elimination of thermal distortion effects realized with the oxy-flame cutting process. See Fig. 6.

2. Equipping the secondary machines with one plasma torch each. This will result in:

   2a. Better utilization of material since the positioning of one torch over the operating field can be more selective than can four oxy-flame cutting torches traveling at 1/4 the speed.

   2b. A-program match between the primary machines and the secondary machines, allowing them to operate from the same program or extension thereof. See Figs. 8 and 9.

   2C. A reduction in labor costs. See Fig. 7

3. Using the powder marking process (see Fig. 14) in place of the center punch marking process thus:

   3a. Eliminating noise.

   3b. Reducing maintenance costs.

   3C. Allowing for an increase in marking speed.

   3d. Permitting the use of sequence number identification of the parts.

4. The use of computer printed labels for part identification, thus eliminating the need to paint stick code individual parts. See Figs. 5 and 15.

SHIPYARDS VISITED DURING THIS STUDY.

Avondale Shipyards, Inc., New Orleans, La.
. Bath Iron Works, Bath, Me:
Bay Shipbuilding Corp., Sturgeon Bay, Wi.
Ingalls Shipbuilding Div., Pascagoula, Ms.
Marinette Marine Corp., Marinette, Wi.
National Steel Shipbuilding and Drydock Co., San Diego, Ca.
Newport News Shipbuilding and Drydock Co., Newport News, Va.
Peterson Builders, Inc., Sturgeon Bay, Wi.
Todd Shipyard, Inc., San Pedro, Ca.

SHIPBUILDING ORIENTED SOFTWARE COMPANIES VISITED DURING THIS STUDY .

Cali Associates, Inc., Metairie, La.
ComputerVision, Inc., Bedford, Ma.
Cutting Technology, Inc., Lexington, Ma.
Cybernation, Inc., Cambridge, Ma.
Shipping Research Services, Inc., Houston, Tx.

COMPANIES VISITED THAT OFFER NESTING SYSTEMS.

Cali Associates, Inc., Metairie, La.
Camsco, Richardson, Tx.
Computervision, Inc., Bedford, Ma.
Cybermation, Inc., Cambridge, Ma.
Shipping Research Services, Inc., Houston, Tx.
*union Carbide Corp., Linde Div. Tonawanda,. NY “

*Visited Linde Division’s part nesting exhibit at the Dallas AWS National Convention.

REFERENCES

1. "A Computer-Aided Design System For Pattern Grading and Marker Making in the Garment Industry." — A. .Castastini, C. Cavagna, U. Cugini and P. Moro CAD 76 Proceedings.

2. "A Method tO Improve Two Dimensional Layout." — Antonio Albano, University di Pisa, Istituto di Scienze dell'Informazione, Corso Italia 40, 56100 PISA-ITALY.

3. "Packing Rectangular Pieces--A Heuristic Approach." — Bengt-Erik Bengtsson, Lund Inst.of Technology, Dept. of Computer Science, Box 725, S-220 07 Lund, Sweden. The Computer Journal, Vol. 25, No. 3, 1982.

4. "The Bottom-Left Bin-Packing Heuristic: An Efficient Implementation." — Bernard Chazelle. IEEE Transactions on Computers, Vol. C-32, No. 8. Aug. 1983.

5. "An Interactive Computer Graphics Approach to the Problem of Nesting of Plane Parts On a Raw Steel Format." — Jorn Oian, Bjorn Hasselknippe and Frank Lillehagen. CAD 76 Proceedings.

6. "Nesting Two-Dimensional Shapes in Rectangular Modules." — Michael Adamowicz, Dept. of Electrical Engineering, Polytechnic Institute of Brooklyn, N.Y. Antonio Albano, Istituto di Scienze dell' Informazione, University di Piss, Corso Italia 40, 56100 Pisa, Italy. CAD 8 (No. 1) 27-33 (Jan. 1976)

7. "A Heuristic Solution Of the Rectangular Cutting Stock Problem." — A. Albano and R. Orsini, Istituto di Scienze dell'lnformazione, University di Pisa, Corso Italia 40, 56100 Pisa, Italy. The Computer Journal, Vol. 23. No. 4, 338-343 Nov. 1980

APPENDIX 1

THE ADVANTAGES AND DISADVANTAGES REALIZED WITH THE OXY-FLAME CUTTING PROCESS.

The advantages are:

1. It is effective over a wide range of material thicknesses. Effective range with most standard machine cutting torches is from approximately 1/4 inch thick material to over 12 inches thick with good quality of cut surface. The maximum thickness cut that is known to the writer is 87 inches.
2. When cutting narrow parts, a multi-torch arrangement can be used with cutting machines, thus increasing . the productivity of the operation.
3. It can very effectively.be used to prepare the various bevels required in the preparation of plate edges for welding.
4. There is no other known process that can compete with the oxy-flame process in effectively cutting contoured sections from heavy steel plate.
5. The initial cost of an oxy-flame cutting torch system is considerably less costly than the cost of a plasma cutting system.

The disadvantages are:

1. In the inch through the 1 inch material thicknesses, the cutting speeds are considerably less than that possible with the plasma cutting process. See. Fig. 6.
2. Preheat is required for starting and maintaining the cutting process. This could take between 20 seconds and one minute depending on the intensity of the

APPENDIX 1 (cont'd)

preheat flame. Depending on the number of pierce starts required, this slows down the cutting process.

3. The process. heat input to the work.piece can cause distortion of the finished product. In the interest of minimizing distortion of the cut parts, certain precautions must be taken in programming the cutting sequence and the direction of the cutting torch travel. In addition, care must be taken by the operator in setting the speed, the direction of the cutting torch travel, the cutting sequence, the fuel gas and oxygen pressures and the preheat high and low levels.

4. The nesting of small Class 3 parts with Class 1 and Class 2 ship parts is often impractical because of the time and the heat distortion involved.

5. The oxy-flame process cannot be used to cut non-ferrous materials. In addition, the process cannot be used to cut stainless steel unless some. energy producing additive such as iron powder is. added to the cutting oxygen stream.

APPENDIX 2

THE ADVANTAGES AND DISADVANTAGES REALIZED WITH THE PLASMA CUTTING PROCESS.

The advantages are:

1. The cutting process is fast and is several times that realized with the oxy-flame process. See Fig. 6.
2. No-preheat is required for starting the cutting process. The piercing start is almost instantaneous. This not only saves time, but it also minimizes the heat input to the work piece. With plasma cutting, the heat affected zone is minimal.
3. Distortion of the plate due to heat input is practically eliminated. With the plasma cutting process, the plate can be completely immeresed in water during the piercing and cutting operations.
4. The use of tabs for joining the cut parts to the main plate is not always necessary for eliminating part movement on the cutting bed.
5. Individual discreet parts can be cut one at a time which simplifies part programming and the nesting of small parts.
6. Both ferrous and non-ferrous metals can be successfully cut with the process.
7. Use of the process can be instrumental in causing a higher plate yield, by making possible the nesting of small Class 3 parts with Class 1 and Class 2 parts without. upsetting the manufacturing process time balance.

APPENDIX 2 (cont'd)

The disadvantages are:

1. The power requirements are high. To effectively cut ship parts at the speed ranges shown on Fig. 6 , 80 to 100 KW per torch is required.

2. Noise and arc glare could be a problem if steps are not taken to minimize or eliminate them. Most plasma cutting operations in the United States are carried out over a water table where the bottom of the plate either touches the water or is slightly above it. In these operation, a water muffler is used to reduce the noise level. The water muffler also helps reduce the arc glare and work piece temperature. In some installations, the plate being cut is completely immersed in water and the cutting is done approximately one to two inches below the surface of the water. The arc glare is greatly reduced and the noise is almost eliminated in these operations. Those using the underwater method claim that the parts produced are more accurate, particularly where the parts being cut are rather long and slender in shape.

3. The effective thickness range of cutting steel plate is up to one inch. Thicker material can be cut, but at a sacrifice in speed, cut surface quality and accuracy.

4. The plasma cutting process is directional. The standard swirl ring used in the torch for handling plasma gas, requires clickwise travel around the work piece. With this process, there is a tendency for the kerf of the cut to have tapered sides. By using the swirl ring in the torch, the taper shifts so that one side

APPENDIX 2 (con't)

is almost vertical, leaving the scrap side of the kerf-tapered. When mirror image cutting is done, one torch must travel in a. counter clockwise direction. In this case, a left-handed swirler must be used in the mirror imaged torch.

5. A study conducted by one user indicates that while there is considerable cost advantage to the user when using the process for cutting ship plate, there is a slight increase in the cost of consumables per foot of cut length over that realized with the oxy-flame cutting process.

APPENDIX 3

SOME ADVANTAGES AND DISADVANTAGES REALIZED WHEN USING SPECIAL SIZED PLATE IN SHIP HULL CONSTRUCTION.

Some advantages are:

1. In the pre-nest assembly of parts on the plate, the operating field are? can be adjusted to best suit the collection of both large and small parts being nested and hence a more efficient nesting arrangement of parts. can often be realized.
2. Segment sizes that best suit the hull construction can be used and the footage of welded joints required reduced.

Some disadvantages are:

1. It causes a delay in order placement in some cases because more detailed engineering design is required in determining the plate sizes to order.
2. It causes an increase in the number of plate sizes required and, therefore, a larger plate storage facility is required to permit the efficient use of grid location assignment.
3. The loss of a plate due to spoilage or dislocation can prove costly because of the additional expense and delay caused by replacing the plate with a similar size or other size considered suitable.
4. The size premium charged by the steel mill plus the hidden increase in plate yard handling expenses could amount to an overall 4% or higher increase in material costs before the plate reaches the burning tables.
5. It causes a cost increase in the production department's scheduling and plate assignment detailing operations. This cost is usually hard to define.

APPENDIX 4

BASIC FEATURES REQUIRED IN A PART NESTING SYSTEM FOR THE SHIPBUILDER.

1. The system to be supplied with a computer work station including:
   - a. A keyboard.
   - b. A 15" or larger CRT screen.
   - c. Graphic capabilities with a light pen or other means for identifying and moving parts.
   - d. A program storage system with a minimum capacity of 10 megabytes.
   - e. A label printer and a device for producing a hard copy of a part or nested program.
2. Local entry and storage of existing part programs written in the format and code used by the machines in the yard or entry and program storage through communication with the main frame computer.
3. Means for:
   - a. Restoring the system information in case of a major systems failure.
   - b. Transmitting parts or nested programs directly to the cutting machines in the DNC system.
   - c. Local means for entering enhancements and modifications to the system.
4. Local generation and storage of part programs from dimensioned engineering **drawings**:
5. Common part program generation through entry of critical dimensions.
6. Scaled display of parts to be nested, with a display of the quantities required of each.
7. Local capability to nest selected parts on assigned plate areas by interactive graphic method.
8. The automatic nesting of parts selected in assigned areas of the plate work piece.

APPENDIX 4 (cont'd)

9. Ability to combine part programs as desired into a defined grouping and the ability to move the grouping as a unit during a nesting procedure.

10. Automatic inventory countdown during the nesting procedure.

11. Movement of any part to any screen location by cursor. or keyboard control.

12. Continuous 360° part rotation.

13. Ability to add or delete parts from the nest and automatically adjust inventory quantities accordingly by keyboard or cursor control.

14. Operator selection of part lead-in location at time of the nest preparation.

15. Operator selection of marking/cutting sequence at time of nest preparation.

16. Rapid traverse moves to be displayed and identifiable on the nest printout.

17. Ability to join parts at the nesting stage.

18. Automatic-part tabbing by cursor or keyboard control.

19. Sequence numbers to appear on the nested part program printout.

20. Optional sequence numbers with scale selection to be part of the cutting machine's marking program.

21. Ability to provide optional check dimensions on the nested program printout.

22. Ability to mirror image any part and nest it.

23. Choice of travel direction.

24. Reaction time to any keyboard or cursor input command not to exceed 10 seconds.

25. Automatic control-for designated minimum spacing of adjoining parts.

APPENDIX 4 (cont'd)

26. Enlarged zoom-in control for examining part intersection areas.

27. Capability of being tied into cutting machine controls through a DNC (Direct Numerical Control) system allowing for part or nested program call-up from the cutting machine's console or operating panel.

28. Automatic printout of part identifications, nest efficiency, the length of the torch's cutting path and the time required to cut and mark the nested program.

29. Ability to produce printed labels with part matching sequence numbers and the part coding information required on each part.